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NON-INVASIVE BLOOD PRESSURE MEASUREMENT SYSTEM

RELATED APPLICATIONS

This application claims priority under 35 U.S.C. §119(e) to U.S. Provisional Application No. 61/366,862, filed Jul. 22, 2010, entitled "System for Triggering a Non-Invasive Blood Pressure Device" and to U.S. Provisional Application No. 61/469,511, filed Mar. 30, 2011, entitled "Non-Invasive Blood Pressure Measurement System," the disclosures of which are hereby incorporated by reference in their entirety.

BACKGROUND

Prolonged reduction or loss of blood pressure in a patient severely limits the amount of tissue perfusion of the patient and therefore causes damage to or death of the tissue. Although some tissues can tolerate hypoperfusion for long periods of time, the brain, heart and kidneys are very sensitive to a reduction in blood flow. Thus, during and after medical procedures and at other times, blood pressure is a frequently monitored vital sign. Blood pressure can be affected by the type of medical procedure performed and by physiological factors such as the body's reaction to the medical procedure. Moreover, blood pressure is often manipulated and controlled using various medications. Medical procedures, physiological factors, and medications can cause the blood pressure of a patient to change rapidly.

The traditional method of measuring blood pressure is with a stethoscope, occlusive cuff, and pressure manometer. Blood pressure cuff instruments make only a spot-check measurement, so repetitive interval measurements are often used to trend patient status. More frequent intervals improve vigilance at the expense of patient discomfort, possible patient injury (e.g., due to occlusion of blood vessels), and excessive battery consumption.

SUMMARY

In certain embodiments, a method of monitoring blood pressure of a patient includes receiving a physiological electrical signal from an electrical sensor coupled with a patient. The physiological electrical signal can reflect electrical activity of the patient's heart. The method may also include receiving a cardiac ejection signal from a second sensor coupled with the patient. This cardiac ejection signal can reflect a cardiac ejection event associated with ejection of blood from the patient's heart. In addition, the method may include receiving an arterial pulse signal from a third sensor coupled with a limb of the patient. The method can also include determining an arterial pulse wave transit time (PWTT) that compensates for a pre-ejection period of a cardiac cycle associated with the patient's heart, based at least partly on the physiological electrical signal, the cardiac ejection signal, and the arterial pulse signal. Moreover, the method may include triggering an occlusive blood pressure cuff to obtain a blood pressure measurement from the patient responsive to a change in the arterial PWTT.

For purposes of summarizing the disclosure, certain aspects, advantages and novel features of the inventions have been described herein. It is to be understood that not necessarily all such advantages can be achieved in accordance with any particular embodiment of the inventions disclosed herein. Thus, the inventions disclosed herein can be embodied or carried out in a manner that achieves or optimizes one advantage or group of advantages as taught herein without necessarily achieving other advantages as can be taught or suggested herein.

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BRIEF DESCRIPTION OF THE DRAWINGS

Throughout the drawings, reference numbers can be used to indicate correspondence between referenced elements. The drawings are provided to illustrate embodiments of the inventions described herein and not to limit the scope thereof.

FIG. 1 illustrates an embodiment of a parameter calculation system;

FIGS. 2A and 2B illustrate plots of plethysmograph and electrocardiograph (ECG) waveforms that can be used to calculate pulse wave transit time (PWTT);

FIGS. 2C and 2D illustrate plots of acoustic waveforms that can be used to calculate PWTT;

FIG. 3 illustrates another embodiment of a blood pressure monitoring system;

FIG. 4A illustrates a plot of acoustic and ECG waveforms;

FIG. 4B illustrates a plot of bioimpedance and ECG waveforms;

FIGS. 5A and 5B illustrate embodiments of blood pressure monitoring systems coupled to a patient;

FIG. 6 illustrates example positioning locations for the acoustic sensors that can be used in the various systems and methods described herein;

FIG. 7 illustrates example positioning locations for acoustic, electrocardiograph (ECG), optical and bioimpedance sensors that can be used in the various systems and methods described herein;

FIG. 8 illustrates an example acoustic sensor that can be used in the various systems described herein;

FIGS. 9A through 9F illustrate embodiments of calculating arterial PWTT;

FIG. 10 illustrates an embodiment of a process for triggering an occlusive blood pressure measurement;

FIG. 11 illustrates plots of PWTT and heart rate waveforms;

FIG. 12 illustrates an embodiment of a dynamic PWTT averaging system.

FIG. 13 illustrates an embodiment of front end circuitry that can be used in the parameter calculation systems described herein to reduce phase impact on the calculations of PWTT;

FIGS. 14A and 14B illustrate an embodiment of a process for calibrating PWTT measurements based on an individualized patient calibration factor.

DETAILED DESCRIPTION

The propagation time of an arterial pulse wave from the heart to an extremity is related to blood pressure. Currently available blood pressure monitoring systems estimate this propagation time by detecting a time difference between points on an electrocardiograph (ECG) waveform and a photoplethysmograph waveform. This estimated propagation time is sometimes referred to as pulse wave transit time (PWTT) or time difference of arrival (TDOA). Currently available blood pressure monitoring systems trigger an automatic occlusive cuff to take a blood pressure measurement based on detected changes in PWTT. When the PWTT has not changed substantially, the blood pressure monitoring system usually does not trigger an occlusive blood pressure measurement. As a result, such a system automatically adjusts the